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A REVIEW ON THERMODYNAMICS ANALYSIS AND WASTE ENERGY UTILIZATION IN CEMENT INDUSTRY

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ABSTRACT

In India, cement manufacturing process consumes about 15-20% energy among all the energy consuming industries. Reduction in energy consumption in cement production process is the prime concern. Therefore, detailed review on the energy use and reserves is essential to find out energy wastage so that essential actions could be applied to decrease energy consumption. In this paper energy use at different sections of cement industries based on the thermodynamic analysis specially Exergy analysis, alternative fuel used for cement kilns, various energy savings measures were reviewed and presented.

KEY WORDS: Exergy Analysis, Cement Industries, Optimization Techniques For Energy Savings Etc

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Original Article

INTRODUCTION

India's cement industry accounted for over six percent of the world's annual cement production. Throughout the years innovation in the cement manufacturing technology, has created with a developing spotlight on manageable and furthermore cost and vitality effective generation. While huge strides may not appear to be noticeable on a year to year premise in Indian cement industry. Industrial sector energy consumption varies from 30% to 70% of total energy used in India. A generous amount of energy consumed in manufacturing of cement. [1]Thermal energy consider around 20–25% of the total cement production cost. The typical electrical energy consumption of a modern cement plant is about 110–120kWh per tonne of cement. Thus concentrate ought to be given on the diminishment of vitality and vitality related ecological discharges. It is important to discover the vitality misfortunes and limit it to bring down the vitality utilization. The Thermodynamic examination is the best instrument for streamlining. [3, 5, 6]

Thermodynamic Analysis and Optimization

Energy consumption represents the largest part of the production cost for cement factories and has a significant influence on product prices (Stanislav Boldyryev, 2016); the major part of the CO_2 emissions from the production of cement is released from the calcinations of limestone (50%) and from the combustion of fuels (40%). [7]Waste heat recovery systems are already in operation in various industries with success. In Canada, the Gold Creek Power Plant [17] has a heat recovery system that produces 6.5MWpower using ORC technology. In India, the A. P. Cement Works with 4 MW and ORC technology is Heidelberger Zement AG Plant, in Lengfurt (Germany) [17] with 1.5 MW power and ORC technology. Another cement industry that uses waste heat recovery (S. Karellas,

2013)

Keeping in mind the end goal to decrease energy utilization in concrete creation process, the cogeneration control plant can recuperate the waste warms to create electrical energy with no extra fuel utilization and along these lines diminish the high cost of electrical energy and CO2 emanations for bond generation. Since the waste heats in cement plant are classified as middle and low temperature waste heat, several power plants are particularly well suited for these waste heats available, [9] such as single flash steam cycle, dual-pressure steam cycle, ORC and the Kalina cycle. (Jiangfeng Wang, 2009)

To carry out a thermo economic analysis, the first step is to define the configuration of the system, which is also known as process flow diagram. The second step is the exergy analysis of the system, in order to calculate the exergy of each flow. The last step is the thermo economic analysis of the system, in which unit exergy costs of each process are calculated among other parameters. Processes which are characterised by having high unit exergy costs will be the less efficient [11, 12, 13]

Exergy examination is a present day investigation device, which is utilized for building forms. Exergy investigation is identified with both the primary law and second law of thermodynamics. [14] The primary reason for exergy investigation is, to distinguish the reasons for the defect of a vitality transformation process. Exergy investigation prompts a superior comprehension of the impact of thermodynamic procedures, on the procedure adequacy, correlation of the significance of various thermodynamic elements, and the assurance of the best methods for enhancing the procedure under thought [8]. A superior comprehension of locales of exergy decimations can help enhance the framework operation and help in better plan and advancement. A higher exergetic execution of a framework converts into vitality funds and ecological advantages. [15-20]

There have been many investigations about the cement part. Among them, there are vital and deductive papers, demonstrating both vitality way to deal with the cement industry and the possibilities and methods for development in vitality utilization of cement industry.

Table 1: Review Based on Thermal Analysis of Cement Manufacturing Process

Author	Objective	Methodology	Conclusion
Jiangfeng Wang, 2009	Exergy analyses and parametric optimizations for different cogeneration power plants in cement industry	Single flash steam cycle, dual-pressure steam cycle, organic Rankine cycle (ORC) and the Kalina cycle are used for cogeneration in cement plant. The exergy investigation for every cogeneration framework is inspected, and a parameter enhancement for every cogeneration framework is accomplished by methods for hereditary calculation (GA) to achieve the greatest exergy productivity.	The exergy losses in turbine, condenser, and heat recovery vapor generator are relatively large, and reducing the exergy losses of these components could improve the performance of the cogeneration system. Contrasted and different frameworks, the Kalina cycle could accomplish the best execution in bond plant.

Stanislav Boldyryev, 2016	The improved heat integration of cement production under limited process conditions: A case study for Croatia	The authors analyzed the energy consumption of a particular cement factory accomplish the best execution in bond plant.	The energy consumption of the cement factory can be reduced by 30%, with an estimated recovery period of 3.4 months. The execution of this retrofit venture helps the plant's productivity and enhances the natural effect of the concrete assembling process.
S. Karellas, 2013	Energetic and exergetic analysis of waste heat recovery systems in the cement industry	Examine and compare energetically and exergetically, two different WHR (waste heat recovery) techniques: a water-steam Rankine cycle, and an Organic Rankine Cycle (ORC).	A parametric study proved that the water steam technology is more efficient than ORC in exhaust gases temperature higher than 310˚C. Finally a brief economic assessment of the most efficient solution was implemented. WHR establishments in concrete industry can contribute fundamentally in the lessening of the electrical utilizations working cost along these lines being an extremely alluring venture with a payback period up to 5 years
Vedat Ari, 2011	Energetic and exergetic assessments of a cement rotary kiln system	Energetic and exergetic analyses of an existing rotary kiln system are presented, and first and second law efficiencies are calculated.	The energy and exergy efficiencies of the existing system are 54.9 and 28.1%, respectively. With the cogeneration, these exergy efficiencies have been obtained to be 70.6% for the use of waste heat recovery steam generator (WHRSG) and 81.5% for the use of heat to pre-heat the raw material, respectively, which dictates a remarkable improvement over the existing system
Ahmet Kolip and Ahmet Fevzi Savas, 2010	Energy and exergy analyses of a parallel flow, four stage cyclone precalciner type cement plant	A mathematical model related to energy and exergy balance for four-stage cyclone precalciner type cement plant is developed. The energy and exergy balances for the whole system and each unit are calculated and presented.	The first and second law efficiencies were 51 and 28%, respectively. Total exergy loss of the system was found to be about 72%.
Adem Atmaca Mehmet Kanoglu, 2012	Reducing energy consumption of a raw mill in cement industry	The first and second law analysis of a raw mill is performed and certain measures are actualized in a current crude plant in a bond production line keeping in mind the end goal to decrease the measure of vitality utilization in crushing procedure. The impacts of surrounding air temperature and dampness substance of crude materials on the performance of the raw mill are investigated	The specific energy consumption for farine production is determined to be 24.75 kWh/ton farine. The use of an external hot gas supply provides 6.7% reduction in energy consumption corresponding to a saving of 1.66 kWh per ton of farine production
DAN SONG BIN CHENA 2016	Extended Exergy Accounting For Energy Consumption and CO_2 Emissions of Cement Industry—A Basic Framework	Exergetic efficiency and CO_2 emission targeted at a typical cement production line are examined in detail with key factors of mitigation being identified.	Some preliminary results are presented

		the future emission trends are simulated based on dynamic prediction with different optimization scenarios in view of current mitigation targets	
Tahsin Engin, Vedat Ari, 2005	Energy auditing and recovery for dry type cement rotary kiln systems—A case study	The energy audit analysis of a dry type rotary kiln system working in a cement plant in Turkey. The kiln has a capacity of 600 ton-clinker per day	About 40% of the total input energy was being lost through hot flue gas (19.15%), cooler stack (5.61%) and kiln shell (15.11% convection plus radiation). Some possible ways to recover the heat losses are also introduced and discussed. Findings showed that approximately 15.6% of the total input energy (4 MW) could be recovered.
C. Koroneos, 2005	Exergy analysis of cement production	involves assessment of energy and exergy input at each stage of the cement production process	It is found that 50% of the exergy is being lost even though a big amount of waste heat is being recovered.
Laila M. sFarag, Anter G. Taghian, 2015	Energy and exergy analyses of Egyptian cement kiln plants	Exergy Analysis	Energetic efficiencies of the plants were found to vary between 41.6 % and 55.5% and their exergetic efficiencies between 26.8% and 35.6% respectively. Energy lost with bypass gas and dust ranges from 724.3kJ/kg clinker for the least efficient process to 200.2 kJ/kg clinker for the highest efficient one corresponding to 16.6% to 6.1% of the total heat input respectively.
G. Kabir, A. I. Abubakar, U. A. El-Nafaty, 2010	Energy audit and conservation opportunities, for pyro processing unit of a typical dry process cement plant	Thermal energy audit analysis was employed, on the pyro processing unit of the cement plant	Thermal efficiency of the unit stands at 41%, below 50–54% achieved in modern plants. The exhaust gases and kiln shell heat energy losses are in significant quantity, amounting to 27.9% and 11.97% of the total heat input respectively. Power and thermal energy savings of 42.88 MWh/year and 5.30 MW can be achieved respectively. Financial benefits for use of the conservation methods are substantial. Environmental benefit of 14.10% reduction in Greenhouse gases (GHG) emissions could be achieve
M. G. Rasul, 2005	Assessment of the thermal performance and energy conservation opportunities of a cement industry in Indonesia	model is developed on the basis of mass, energy and exergy balance and is applied to an existing Portland cement industry in Indonesia	The thermal energy conservation opportunities are identifiedThis investigation demonstrate that by supplanting industrial diesel oil (IDO) with squander warm recuperation from oven and cooler fumes for drying of crude feast and fuel, and preheating of burning air, a security industry in Indonesia can save around 1.264 ×105 US dollars for each year.

Ziya Sogut, Zuhal Oktay, 2008	Energy and exergy investigations in a warm procedure of a creation line for a concrete manufacturing plant and applications	Determine the actual energy losses by performing energy and exergy analyses and to evaluate energy and exergy efficiency in each process for the cement factory. In these examinations, for each procedure energy and exergy graphs have been constituted on the creation line.	Efficiencies (energy/exergetic) of the processes for the raw mill, the rotary kiln, the trass mill and the coal mill on the production line have been found as 84%/25%, 61%/49%, 74%/13%, 74%/18%, respectively.. What's more, a few proposals concerning the diminishment of energy misfortunes have been proposed.
M. Z Sogut,Z OKTEY,A Hepbasli2009	Energetic and exergetic assessment of a trass mill process in a cement plant	The main objective of this study is to assess the performance of a trass mill in a cement plant based on the actual operational data using energy and exergy analysis method	The overall exergy efficiencies are found to be slightly less than the corresponding energy efficiencies; e.g. 74% and 10.68% for energy and exergy efficiency, respectively. Using energy recovery systems, waste heat energy may be captured, while energy and exergy efficiency values can be improved to 84% and 48%, respectively.
Ziya Sogut, Zuhal Oktay, 2011	Impact assessment of CO_2 emissions caused by exergy losses in the cement sector	An exergy analysis is carried out for all of the thermal processes of the cement plant. Then exergy losses and carbon dioxide (CO2) emissions of the rotary kiln process taken exemplary according to annual dead state temperature changes are determined.	Annual averages of the exergy efficiency of the kiln and its exergetic improvement potential are found as 48.5% and 110.58 GJ/h, respectively. In this system, CO2 emissions caused by exergetic losses are calculated for the coal mixture and the natural gas as an average of 38,004 kg/h and 12,668 kg/h, respectively. **Toward the finish of the examination, a few proposals concerning lessening of the worldwide impacts for these frameworks are made..**
Ziya Sogut, Zuhal Oktay, Hikmet Karakoç, 2010	Mathematical modeling of heat recovery from a rotary kiln	In this study, heat recovery from rotary kiln was examined for a cement plant in Turkey. At initial, an exergy investigation was completed on the operational information of the plant. A mathematical model was developed for a new heat recovery exchanger for the plant	Ss
Zafer Utlu, Ziya Sogut, Arif Hepbasli, Zuhal Oktay, 2006	Energy and exergy analyses of a raw mill in a cement production	Perform energy and exergy analysis of a raw mill (RM) and raw materials arrangement unit in a bond plant in Turkey utilizing the genuine operational information.	Proposed as a valuable instrument in the examination of vitality and exergy use, creating vitality strategies and giving vitality preservation measures.
G. V. Pradeep Varma T. Srinivas, 2016	Parametric analysis of steam flashing in a power plant using waste heat of cement factory	A case study has been conducted at a cement factory, Telangana, India with cogeneration plant having flashing technology.	The recognized key operational parameters are steam producing weight, point of confinement to high weight blazing, breaking point to low weight glimmering and blaze mass proportion

Energy Recovery from Waste to Utilize in Cement Plant

The cement manufacturing process is an energy exhaustive process. It yields weighty pollution and utilizes large amounts, on non-renewable resources. With increasing pressures to reduce greenhouse gas emissions, due to cement

manufacture, research and development of fuel alternatives and their effect on the manufacturing process, has become an industry focus. The cement industry is a Resource Intensive Industry (RII), with use of large quantity of natural resources as Raw materials and Fuels. [21-22] The known fossil fuels and more importantly Coal, which is the primary fuel for Indian cement industry is fast depleting, it is imperative to look for alternatives. The cement industry is capable to co process wastes as alternate fuels and raw materials, to reinforce its competiveness and at the same time, contribute to solutions to some of society's waste problems in a way, which valorises the waste and is beneficial to the environment.[24] The different studies done by different researchers are tabulated in Table 2 and 3, on the same era.

Table 2: Recent Studies Based on Energy Recovery from Waste to Utilize in Cement Plant

Author	Objective	Methodology	Conclusion
K.T. Kaddatz, et al. 2013	To meet the requirements of testing and implementing selected alternative fuels.	Simulation of three alternative fuels, namely spent carbon lining, used industrial lubricants and used tires, for identifying the most effective fuel source among these three. Aspen Plus software was initially selected to model the cement manufacturing process	Among the selected fuels used, industrial lubricant is found to be the best option regarding the CO2 emission, while the spent carbon lining is the worst one. In contrast, feed material requirements can be reduced by up to approximately 15% by using spent carbon lining
Emad Benhelal, Alireza Rafiei 2012	Evaluate the air pollution reduction through fuel substitution of coal with fuel oil, natural gas and palm kernel shell.	This paper introduces the re-enactment of concrete process utilizing elective energizes to supplant coalPyro-processing stage of the conventional cement manufacturing process was simulated by Aspen HYSYS	Simulation results revealed that the substitution of fuel oil, natural gas and palm kernel shell for coal had a critical commitment for emanation decrease in concrete industry.
U. Kaantee et al 2004	The goal is to optimise process control and alternative fuel consumption, while maintaining clinker product quality	In order select a suitable alternative fuel, a commercial modelling tool (ASPEN PLUS) is used to model the four-stage preheater kiln system of a full-scale cement plant using petcoke as fuel. Counts with elective fills are finished by incompletely supplanting the essential or auxiliary fuel. Meat and bone meal (MBM) and sewage slime are considered	Dependence of process performance on the amount of combustion air is clearly demonstrated The vitality demand of the procedure could be anticipated for differing fuel blends
Azad Rahman et al 2014	Aspen Plus based simulation for energy recovery from waste to utilize in cement plant pre heater tower	A process model of the pre heater tower is developed using Aspen Plus simulation software based on the combustion mechanism. The model is verified against measured data from industry and data available in the literature.	That maximum 3% increase of energy efficiency and 2.5% reduction of CO2 can be achieved by using tyre for about 25% of thermal energy requirement. Recreation comes about displayed in this paper offer a rule for actualizing chose squander inferred powers in bond industry.
Seyed Ali Ashrafizadeh et al, 2012	Exergetic and environmental performance improvement in cement production	The burning system of the cement production (kiln & pre heater) process was simulated in four thermal areas.	it was shown that the secondary burner application can reduce the exergy losses about 25 percent, which leads to a reduction of the greenhouse gases of about 35000 cubic meters per year for

	process by driving force distribution		each ton per day of clinker production

Table 3: Different Industrial Waste used as Alternative Fuel in Cement Production

Fuel	Suitability	Reference
Spent carbon lining	• Its ability of offset a portion of the feed material required • Limited though by its sodium content • Easiest to execute as the capacity, taking care of and nourish necessities are fundamentally the same as that for coal and would require negligible changes.	K. T. Kaddatz, et al. 2013
Used industrial lubricants	• Energy content for the used lubricants analysed was the high • Produced the low overall carbon dioxide emissions • The co ordinations of utilizing waste ointments is genuinely straightforward and would require insignificant changes to the present plant Largest adjustment would be the range required for the capacity, pumping and mixing	
Used tires	• The tires had a high energy content allowing them to provide a better emissions profile than coal. • The biggest shortcoming with utilizing this alternative is that tires requires a convoluted taking care of setup which regularly incorporates a lot of manual taking care of.	
Fuel oil	• Second largest pollution emitter after coal since produces 31,400 kg/h CO_2 and was the first SO_2 producer.	Emad Benhelal, Alireza Rafiei 2012
Palm kernel shell	• Reduced 46.16 % of CO_2, 73% of NO_2 and 68% of SO_2 emissions as compare to burning coal.	
Natural gas	• Mitigated 45.64 % of carbon emissions and produced neither NO_2 nor SO_2.	
Meat and bone meal (MBM) and Sewage sludge	• The air demand is higher with the new fuel than for the coal, it means that the kiln fans must run at higher speed to supply the bigger air sums. Then also the exhaust gas amounts are larger, which will affect the whole function of the pre-heating system as a whole.	U. Kaantee et al 2004, Azad Rahman 2014

CONCLUSIONS

Cement manufacturing is an energy intensive process. This review paper explains Thermodynamic analysis of cement manufacturing plants along with use of alternative fuels or waste heat recovery was analyzed by various researchers. Amongst the different segments, grinding consumes about 60% of total energy consumption in a cement plant. Energy loss is maximum in grinding process. Therefore, enhancements can be made in this section to decrease heat loss or recycle heat. Use of alternative fuels or waste heat recovery could be a good solution. However, challenges associated with the use of alternative fuels must be overcome. This could be a potential area for future research and development.

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